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RECOVERY OF COPPER FROM PCB LEACH SOLUTION BY SOLVENT EXTRACTION

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ABSTRACT

Discarded computers, mobiles and other consumer electronics (e-waste) are the fastest growing portion of the present day waste stream and are considered hazardous wastes due to the presence of several toxic metals. However such waste can be considered as valuable resource several valuable metals like copper, silver, gold etc. In the present study attempts have been made to recover copper from the leach solution of electronic wastes particularly from PCBs of computers and mobile phones. The metal rich concentrate obtained from the beneficiation circuit is leached in sulphuric acid to dissolve different metals such as copper, zinc, nickel, aluminium, iron etc. The leach liquor obtained contained 23.98 g/l Cu, 0.26 g/l Ni, 0.003 g/l Co, 1.7 g/l Zn, 0.0035 g/l Cd, 0.9 g/l Fe. This solution was further subjected to solvent extraction using LIX 84IC and Acorga M 5640 for the separation and recovery of Cu selectively from the leach solution. Various parameters were studied to optimize the conditions for maximum extraction of copper by both the solvents and their extraction efficiency has been compared. The Mc-Cabe Thiele plot shows the requirement of three stages with O/A ratio of 2:1 for quantitative extraction of copper from the leach liquor at pH 1.7 with 25% LIX 84IC. The counter current simulation studies with O/A ratio of 2:1 up to six stage shows almost complete extraction of copper along without co-extraction of other metals. Finally stripping of copper from the loaded organic phase was performed at different concentration of H_2SO_4 (2.5–15%, v/v). The stripping efficiency is increased with increasing sulphuric acid concentration.

Keywords: *E-waste, Copper extraction.*

INTRODUCTION

E-waste is becoming a major concern due to the increasing quantities and toxicity of the substances present in it. Its disposal without adequate treatment poses health hazards, affecting human beings, soil, and the ecosystem. Only 5% of the e-waste generated in India is recycled in the formal sector. Rest all goes to the informal sector for recycling thus posing risk to environment in terms for air, water and land pollution. With growth in IT industry in India, the e-waste generation is expected to increase many fold. By the end of 2012, the e-waste generation is expected to be around 16,00,000 MT[1]. Composition of e-waste is very diverse and differs from product to product. It contains more than 1000 different substances such as ferrous and non-ferrous metals, plastics, glass, wood & plywood, printed circuit boards, concrete and ceramics, rubber etc. These wastes falls under the hazardous category due to the presence of several metals both toxic metals and plastics, hence their proper handling is important. The conventional treatment methods such as

landfill and incineration are not advisable due to the pollution threat to the environment and loss of several valuable metals.[2, 3]

The present practice of pyrometallurgical method involves process steps such as incineration and smelting which enables effective recovery of metals such as copper and precious metals along with the generation of high amounts of pollutants and multiple metals-containing slag.[4, 5]

Because of the complex composition of the e-waste, its recycling and treatment for the recovery of all the metals may not be possible, however the recovery of a few precious and valuable metals such as gold, silver, copper, lead, zinc, nickel etc. can be recovered by the hydrometallurgical route. Composition wise copper is the major metallic component in the e-waste, hence a process for its selective recovery by beneficiation, leaching and solvent extraction/ion exchange route is explored in the present investigation. Various methods are proposed to separate, seggrate and beneficiate the e-waste to remove unwanted impurities[6–8] before its dissolution. Various leachants such as nitric acid[9–11] ammonium sulfate and chloride solutions[12], sulfuric acid and HCl have been used to bring the metals in the solution. Copper from both acidic and ammoniacal containing various other metals such as Zn, Pb, Mn, Cd, Ni, Co was recovered by solvent extraction[13–16] using several commercially available chelating type of solvents such as LIX64, LIX 84, LIX 6022, LIX 860, PT 5050, and PT 50[16] etc.

Present study focuses on the recovery of copper from e-waste concentrate by sulphuric acid pressure dissolution and selective extraction of copper from leach solution using both LIX 84 IC and Acorga 5460 diluted with kerosene.

MATERIALS AND METHODS

This study deals with the recovery of copper from computer waste. The discarded computer was first dismantled to segregate various components such as CRT tubes, PCB, plastic parts, copper wires, PCB etc. PCB's were then processed by various mineral processing units to make a metal rich concentrate. The electronic waste concentrate of composition: 36.3% Cu, 3.01% Zn, 10.8% Fe, 9.6% Al, 9.4% Pb, 8.8% Sn, 0.027% Ag and 0.017% Au, was subjected to pressure dissolution in sulfuric acid at 150°C. Concentrations of Cu, Ni, Co, Zn, Cd, $Fe,^{+}$ ions in the leach solution were determined by atomic absorption spectrophotometer (Solaar AA Spectrometer).The leach liquor with composition: Cu:-21.59g/l, Ni:-0.26g/l, Co:-0.003g/l, Zn:-1.5g/l, Cd:-0.002g/l, Fe:-0.85g/l was subjected to metal separation by solvent extraction using LIX 84 IC and Acorga M 5420. Both the solvents were diluted with kerosene to get the solvent of the desired concentration. The appropriate volume of aqueous solution containing metal ion was mixed with 10ml of a known concentration of the solvent at an organic/aqueous phase ratio of 2 in a separatory funnel and shaken for the predetermined time interval. All the experiment studies were carried out at 30°C. The aqueous and the organic phases were separated, and the metal concentration in both the phases were analysed by Atomic Absorption Spectrophotometer (AAS). Effect of various parameters such as time of equilibriation, pH of aqueous feed, solvent concentration, O/A phase ratio, etc. were optimized. The initial pH of the aqueous feed was adjusted by using sodium hydroxide or sulfuric acid. Stripping of the metals from the loaded solvents was performed in a similar way by contacting the loaded organic solvent with sulphuric acid solution of different concentrations.

RESULTS AND DISCUSSION

Experiments were conducted to study the effect of various parameters to optimize the best conditions for maximum extraction of the metals such as concentration of the organic phase, pH of the aqueous feed, shaking time, organic to aqueous phase ratio variation etc by LIX 84 IC. Results on the extraction of copper by LIX 84 IC were compared with the copper extraction with Acorga M 5460.

Effect of concentration of Acorga M5640 and LIX 84 IC

Concentration of Acorga M 5640 and LIX 84 IC were varied from 10% to 40% in kerosene. Fig. 1 shows that with the increase in Acorga concentration from 10 to 40% there is an increase in percent copper extraction from 52.2 to 90.6% and with LIX 84 IC the percent copper extraction increases from 47.1 to 78.3 % with the increase in LIX 84 IC concentration from 10 to 40% at organic/aqueous ratio of 2:1, room temperature and mixing time 5 minutes. Thus Acorga M 5640 appears to be a better solvent than LIX 84 IC for copper extraction.

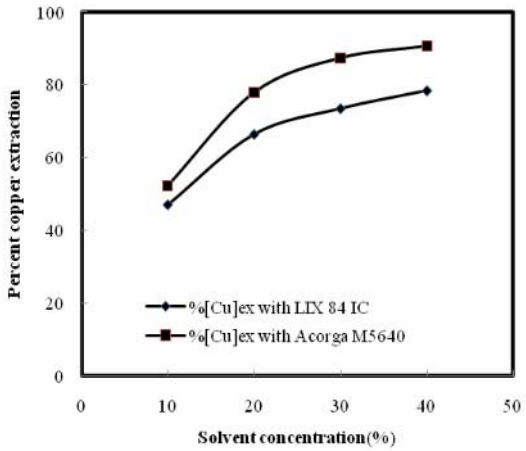

Fig. 1: Effect of variation in solvent concentration (LIX 84 IC and Acorga M5640) in Kerosene. O/A: 2/1, T 30°C, t: 5 min

Effect of initial pH of the feed solution

Initial pH of the aqueous solutions was varied in the range 0.4 to 3.0. Results show that percentage extraction of copper increases from 58.08 to 83.3 with 20% Acorga M 5460. Other parameters were kept constant at a temperature of 30°C, organic/aqueous ratio 2:1, concentration of the feed solution Cu:-21.59g/l, Ni:-0.26g/l, Co:-0.003g/l, Zn:-1.5g/l, Cd:-0.002g/l, Fe:-0.85g/l, and mixing time 5 minutes. Fig. 2 shows the co-extraction of 85% of Cd as the pH increases upto 3, however the amount of Cd is only .002g/ in the feed solution which can be easily scrubbed before stripping of copper. Ni and Zn extraction were negligible.

Similar experiment was conducted using 25% LIX 84 IC keeping other parameters same as above. Fig. 3 shows that with the increase in initial pH of the aqueous feed from 0.4 to 3.0, copper extraction increases from. 43.35% to 81.6%. Ni extraction is only up to 0.65% and Cd extraction is upto 1.18%.

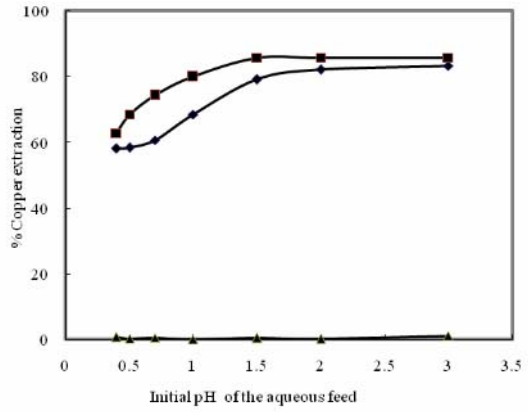

Fig. 2: Effect of initial pH of the feed solution using 20% Acorga M 5640. O/A: 2/1, T 30°C, t: 5 min.

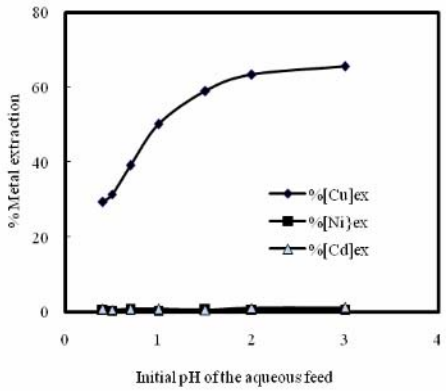

Fig. 3: Effect of pH variations in feed solution (using LIX 84 IC). O/A: 2/1, T 30°C, t: 5 min.

Effect of mixing time of aqueous with organic phase

Mixing time of aqueous and both the organic phases was varied from 1to 10 minutes. The percentage of Cu extraction increased from 77 % to 79% for LIX 84IC and from 81 to 83 % for Acorga 5640, hence 2 min of mixing was found to be sufficient for the extraction of Cu. Beyond this time the percentage extraction was constant, hence in all the experiments mixing was done for 5 minutes to ensure complete extraction. Other parameters were kept constant as the room temperature, concentration of Cu in feed solution 21.59 g/l, the pH of the solution which was 1.7.

Extraction isotherm for Cu extraction

Organic to Aqueous ratio was varied from 5:1 to 1:5. It was observed that there was an increase in Cu extraction from 20 to 93% and 12 to 97% with the increase in O/A from 1:5 to 5:1 for 25% LIX 84 IC and 20% Acorga M 5460 respectively. Other parameters were kept constant such as the mixing temperature at 30°C, initial pH of the aqueous feed was 1.7, concentration of Cu in feed solution was 21.59g/l and mixing time of 5 minutes. To determine the no. of stages required at a chosen volume phase ratio, Mc-Cabe thiele plot was drawn between the [Cu]aq vs [Cu] org obtained at varying O/A ratios as shown in Fig. 4. As can be observed from Fig. 4 that 100% extraction of Cu was possible in two counter current stages at O: A ratio of 2:1.

Further the saturation loading capacity of both the solvents was determined by multiple contact method. The fresh aqueous feed containing Cu:-21.59g/l, Ni:-0.26g/l, Co:-0.003g/l, Zn:-1.5g/l, Cd:-0.002g/l, Fe:-0.85g/l were contacted with same loaded organic each time at organic/aqueous phase volume ratio of 1:1 at equilibrium pH 1.7 at 30°C. Thus after three contact the loaded organic contains 20.98 g/L Cu, with 20% Acorga M 5640 and 17.94 with 25% LIX 84 IC with a very negligible extraction of Zn at O/A ratio of 2:1. Other metal ions did not show any affinity for this solvent.

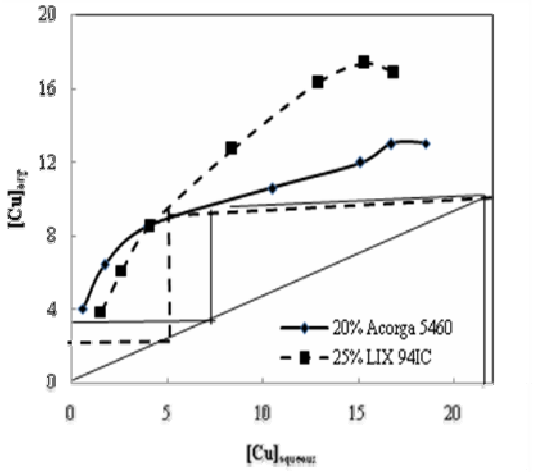

Fig. 4: Mc- Cabe- Thiele plot for stage determination for complete metal extraction. T 30°C, t 5min, [Aq feed]g/L Cu:-21.59, Ni:-0.26, Co:-0.003, Zn:-1.5, Cd:-0.002, Fe:-0.85.

Sufficient quantity of Cu loaded organic phases was generated by repeated contact of same loaded organic with fresh aqueous feed each time at an equilibrium pH of 1.7. It was scrubbed to strip trace of Zn co extracted with Cu and copper was stripped with a Known concentration of H_2SO_4 to strip out copper in a purified form.

CONCLUSION

Study on extraction of copper from e-waste leach liquor containing Cu: 21.59g/l, Ni: 0.26g/l, Co: 0.003g/l, Zn: 1.5g/l, Cd: 0.002g/l, Fe: 0.85g/l were conducted using Acorga-M5640 and LIX 84 IC.

- Results showed that Acorga-M5640 is a more efficient extractant compared to LIX 84 IC.
- On varying the LIX 84 IC concentration in the range of 10–40%, upto 78% of copper can be extracted at an initial aqueous feed pH = 1.7 at O/A phase ratio = 2:1 and contact time of 5 minutes, on the other hand upto 91% of copper can be extracted using Acorga-M5640 under similar conditions.
- On varying the pH from 0.4 to 3, the percent extraction of copper increases upto 80% with 25% LIX 84 IC and upto 84% with 20% Acorga-M5640.
- Studies on extraction of copper on varying time interval, at pH = 1.7 at. O:A = 2:1 with 20% Acorga M 5640 shows a maximum extraction in 5 minutes beyond which the extraction becomes constant.
- A complete recovery of copper could be obtained in two counter current stages with both the solvents at pH = 1.7, phase ratio 2:1 and contact time of 5 minutes.

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